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SUMMARY REPORT -- 1971-1975
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Department of Environmental Horticulture
University of California, Davis

Richard W. Harris
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EXPERIMENT STATION

PLANT TOLERANCE TO FLOODING

Richard W. Harris, Andrew T. Leiser, and Robert E. Fissell*
Department of Environmental Horticulture
University of California, Davis

Abstract

California reservoirs built primarily for flood control, power generation and irrigation storage are unsightly much of the recreation season due to the barren shoreline when the reservoirs are below their gross pool levels. Plants that could withstand two to four months of flooding would extend vegetation over significant shoreline areas for most of the recreation season.

Twenty-two selections of 20 species of plants were tolerant to at least 50 days of flooding. Thirteen species survived more than 100 days of flooding; and one species is growing in water since shortly after planting two and a half years ago. Seven of these species have withstood 114 or more days of complete inundation during one or more years. These seven species exhibited enough tolerance to flooding to vegetate Folsom Lake to the water's edge for at least four months during the recreation season in seven out of the last 10 years.

Trees established one growing season before being flooded were no more tolerant to flooding than those planted only two months before flooding. In fact, at Davis the year-older (and taller) trees were more subject to trunk bending when flooded than were the younger trees.

Severe pruning of young trees immediately prior to flooding decreased tolerance to flooding.

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*Frank Chan assisted in the survey of Andrus and Brannan Islands during July, 1974.

Species exhibiting tolerance to flooding, 1969, 1972-1974.

Considerable Tolerance

Cynodon dactylon 'Tiff Green'	Tiff Green hybrid bermudagrass
Eucalyptus camaldulensis	Red gum
Platanus acerifolia	London plane tree
Salix alba 'Tristis'	Golden weeping willow
Taxodium distichum	Bald cypress
Washingtonia robusta	Mexican fan palm

Moderate Tolerance

Carya illinoinensis	Pecan
Fraxinus pennsylvanica var. lanceolata	Green ash
Gleditsia triacanthos var. inermis	Thornless honey locust
Salix sp. Terminus South	Willow
Salix sp. Terminus North	Willow
Salix sp. Folsom	Willow

Tolerant

Acacia decurrens	Green wattle
Acer saccharinum	Silver maple
Cephalanthus occidentalis	Buttonwillow
Platanus occidentalis	American sycamore
Populus candicans	Balm of Gilead
P. x canadensis	Carolina poplar
P. fremontii	Fremont poplar
Quercus lobata	Valley oak
Salix matsudana	Corkscrew willow
S. piperi	Dune willow

Introduction

The draw-down areas of reservoirs usually present unattractive shorelines for recreation purposes. Interest in the possibility of revegetating these areas lead to this project to identify plant species that would be tolerant of periodic flooding.

To evaluate plant tolerance to flooding, two sites were established in 1972. One was at the University of California, Davis and the other at Folsom Lake State Recreation Area east of Sacramento. In addition, a survey of Andrus and Brannan Islands in the San Joaquin delta was conducted to assess tree tolerance to the flooding that occurred between June 21, 1972 and the end of that year. A summary of a similar survey in 1969 of Sherman Island is also included.

Experimental Approach

Although the project was funded for five years, it was not possible to begin until the spring of 1971. The first year's funds were used to construct the flooding reservoir at U. C. Davis during the summer of 1971. This reduced, to three, the number of growing seasons for evaluation of plants. Therefore, the plants obtained were primarily from commercial nurseries so as not to further delay beginning the study and shortening the testing period. This does have the advantage that most of the species found to be tolerant would be available from commercial sources.

Experimental Sites

(See the July 1, 1974 Progress Report for details)

Flood Reservoir, U. C. Davis

A one-acre portion of the water channel of the Wildlife and Fisheries Biology Environmental Ecosystem was graded to have an 8:1 slope on the east and a 4:1 slope on the west, Figure 1. Dikes and weirs make it possible to control the water level through a range of about 7.5 feet.

The Flood Reservoir was divided into three blocks or replicates. The species were set in rows perpendicular to the contour at 1-foot intervals in elevation so there were at least two trees of each species at each elevation in each of the three blocks of trees. Half of each block was planted in 1972; the remaining half in 1973. The areas was fenced to keep out rabbits. A monthly weed-control (Paraquat) and irrigation schedule was maintained during each growing season.

1972. Twenty species were planted in January and an additional eight *Eucalyptus* species in May.

1973. During February and March, 24 species were planted in the remaining portions of the three blocks. Nineteen of the 24 species also had been planted in 1972.

1974. Three different willow species, as yet unidentified, from Folsom Lake and Terminus Reservoir, Tulare County, were propagated by cutting in 1973. One-gallon can plants were planted out in February, 1974. The mother plants were seven to 10 years old and had withstood 45 to 277 days of flooding each year.

Three grass species, *Agropyron intermedium* 'Oahe', *Phalaris arundinaceae* and *Festuca arundinaceae*, were seeded in December, 1973 in 18-inch-wide strips running east and west across the reservoir in each of three replications, Table 6, Figure 2. The turf species established well and required two mowings before flooding began in May. 'Tiff Green' bermudagrass was sodded in March, 1974. It grew little before being flooded.

Flooding. The reservoir was not flooded during 1972. However, water flowed along the bottom of the reservoir keeping the soil saturated along the lowest row of trees.

Flooding of the reservoir at Davis began on April 26, 1973. By May 13 the water was at maximum level with 5 trees of each species in each block flooded.

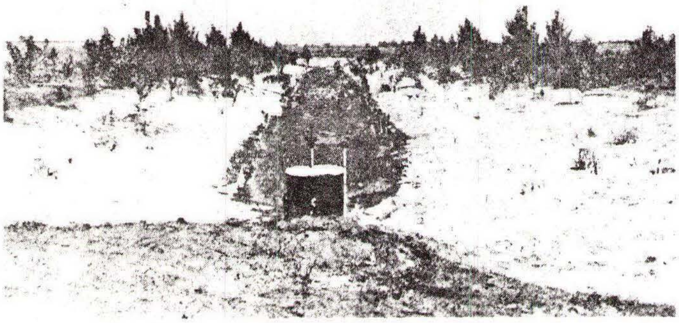


Fig. 1. Flood Reservoir, Davis from the south end about a month after water was lowered. The overflow standpipe is in the foreground. The slope on left is 4:1 and on right 8:1. Water has flowed along bottom, as shown, since April, 1973. Photo September 1973.

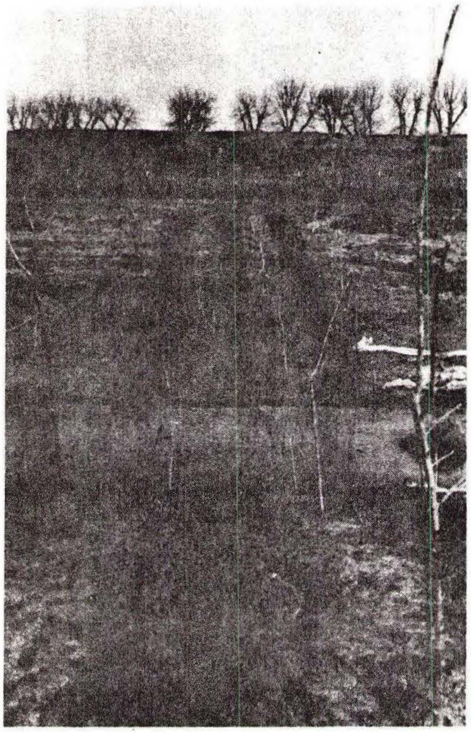


Fig. 2. The three species of grass seeded in December, 1973. Photo taken in March 1974 before the bermudagrass was sodded. Flood Reservoir, Davis.

Water was supplied from Lake Berryessa in the coast range by the U. C. Davis irrigation system. Water input was more than 2.4 acre feet per day to fill the reservoir and about 0.8 acre feet per day to maintain the water level. The Yolo loam soil was quite porous. At gross pool, the water surface was about 0.75 acre. Evapotranspiration and percolation averaged about 12 inches of water per day. With this amount of water added, the water temperature remained fairly uniform during the flooding period and the dissolved oxygen level was similar to that of a large reservoir, such as Folsom Lake (Table 2, 1974 Progress Report). In July, water temperature throughout the 8-foot depth ranged between 71°-73°F and the dissolved oxygen level 6.1-8.1 mg/l.

Folsom Lake

The Folsom Lake site is on an east facing slope between dikes 7 and 8 west of the boat launching ramp at Folsom State Recreation Area in Sacramento County.

1972. On February 16, one tree of each of 16 species was planted at each of nine contour elevations. The contours were at 4-foot intervals from 434 to 466 feet elevation. The Lake level was 423 feet when the trees were planted. The 15 deciduous, bare-root trees were cut back to a height of two to four feet depending on species. The one evergreen, Acacia melanoxylon, had a third of its foliage removed.

A 10-inch diameter cylinder of wire fencing 3-feet high was placed around each tree to protect from deer and rodents. A 30-inch diameter watering basin was formed around each tree at planting time. Beginning on March 7 and monthly thereafter the tree basins above water were sprayed for weeds (Paraquat or Dalapon) and filled with water.

1973. On March 28, 22 species of plants were planted in the same area midway between the rows of the 1972 plantings. Eight trees of each species were planted, the lowest at 436 feet and the highest at 464 feet elevation. Eleven species were the same as planted in 1972, six of which survived 82 or more days of flooding in 1972.

The trees planted in 1973 were protected, weeded and irrigated as in 1972.

1974. The three selections of willow planted at Davis were planted at Folsom in February.

Flooding. The reservoir level depended on the runoff from the reservoir watershed and the water release practices, Table 4.

Andrus-Brannan Islands Survey

Large portions of these two islands were flooded from June 21 to the end of December, 1972. The maximum depth of water at which trees survived ranged from 2.5 to 15 feet. The soil surface had water covering it for up to 125 days.

In July, 1974, the islands were surveyed for live and dead trees and shrubs; species, location, site elevation, and plant condition were noted. Plants were considered tolerant if they met one of the following three criteria:

	Number of Plants/Species	% Plants Survived More Than 60 Days of Flooding
1.	5-20	100
2.	20-50	90
3.	>50	75

Length of flooding was determined from the water depths on specific dates during the flood period.

Results

Experimental Plantings

Eleven species exhibited considerable tolerance to flooding in the two experimental plantings two years at Davis and two or three years at Folsom, Tables 1, 3 and 5, Figures 3 and 4.

Species-Considerable Tolerance

Three of these species exhibited the greatest tolerance to flooding having withstood complete inundation at Folsom for at least three months each year. Plants with such tolerance would have provided vegetation at Folsom to the water's edge 130-166 days during the recreation season in seven out of the last 10 years. Or more than half of the draw-down area could have vegetation the entire year during this 10-year period.

Salix alba tristis tolerated flooding well at both Davis and Folsom, Table 1. In fact, two trees have stood in water continuously since December, 1972, a period of two and a half years. *Eucalyptus camaldulensis* was quite tolerant to flooding in 1973, but some plants at the lower elevations that survived 1973 died in the winter of 1974 after being flooded for more than 102 days in 1974. The long flooding period may have increased plant susceptibility to cold temperatures at Folsom in January, 1975 when temperatures reached 25°F.

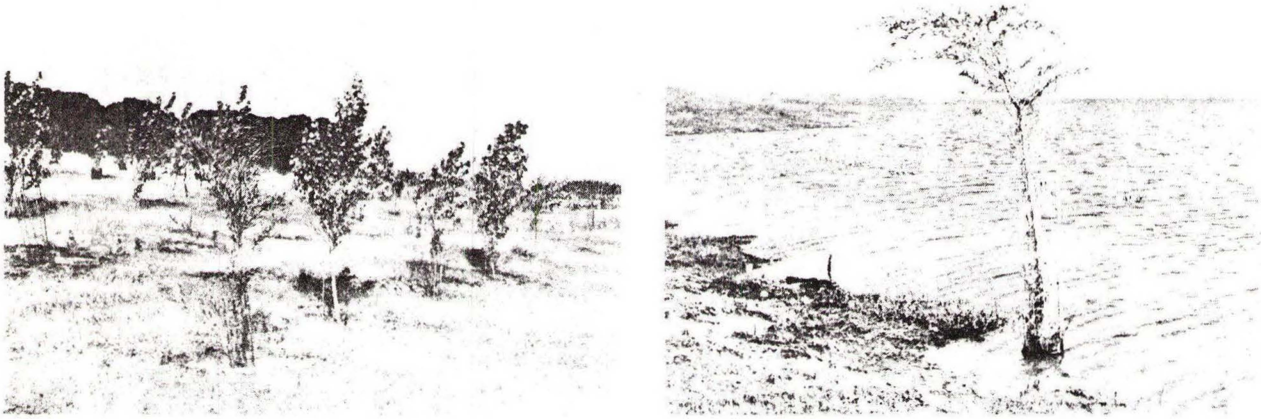
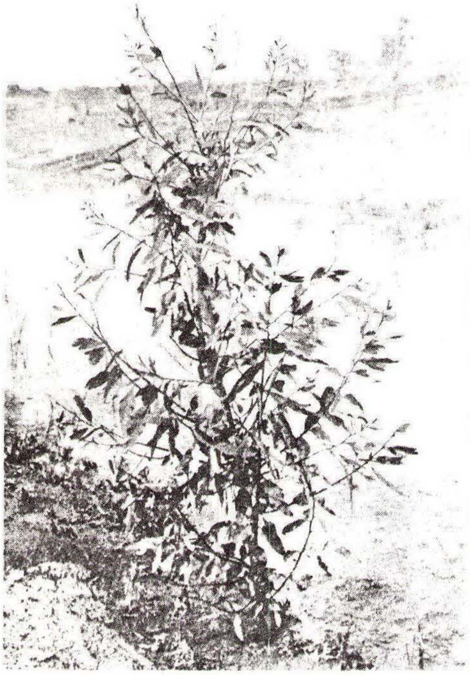


Fig. 3. Folsom Lake. Left, (l. to r.) *Salix alba* 'Tristis', *Populus fremontii*, *P. canadensis*, *P. candicans* and *P. alba* at 454 foot elevation 10 feet below gross pool, which withstood 82 days of flooding in 1972 and 55 days in 1973. The trees are 5 to 7 feet tall.

Right. *Salix alba* 'Tristis' at 442 foot elevation, 22 feet below gross pool. The tree was flooded 147 and 140 days in 1972 and 1973 and completely inundated for 3 months both years. Tree 6 feet tall. Photos taken September, 1973.



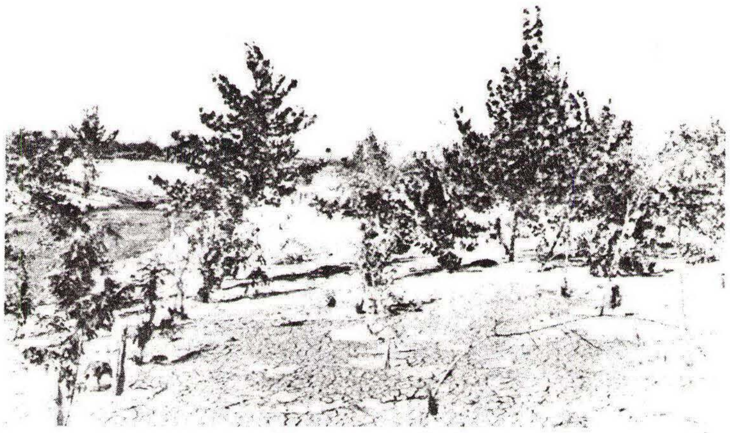


Figure 4. Flood Reservoir, Davis. Above. East bank of Reservoir after 1973 flooding. Note large Populus fremontii (left center) growing 5 feet below gross pool level which was flooded for 100 days. This tree planted in 1972 was about 12 feet tall by the end of 1973. Note algae on soil. Photo September 1973. Left. Eucalyptus camaldulensis, planted in 1972, 6 feet below gross pool level. Tree was completely inundated for 100 days in 1973. Tree was about 4 feet tall when photographed in March, 1974.

Taxodium distichum was the most tolerant species at Folsom withstanding 166 and 190 days of flooding in 1973 and 1974. At Davis, only 38% of the plants survived 100 days of flooding in 1973. Two-thirds of the remaining plants survived a similar period of flooding in 1974. The delayed planting at Davis in 1973 may account for the greater loss at Davis than at Folsom; the plants were small, bare-root material that could have been less able to withstand flooding. Other reports and the Andrus Island survey substantiate the tolerance of Taxodium distichum, Table 7.

Species - Moderate Tolerance

An additional three species were almost as tolerant as the three listed above, Table 1. Although two of 19 trees of Fraxinus pennsylvania var. lanceolata did not survive 100 days of flooding in 1973 at Davis, one tree of that species stood in water more than 500 days before failing. All of the remaining 17 trees withstood 100 days of flooding in 1974. At Folsom the species withstood at least 82, 86 and 125 days of flooding during 1972, 1973 and 1974 respectively.

The Gleditsia tricanthos var. inermis was almost as tolerant with six of eight trees surviving 100 days of flooding in 1973 and 16 of 16 trees flooded in 1974. One tree survived for 500 days in 1973 at Davis. Survival at Folsom was not as good in 1972, but the 1973 plantings survived 60 and 102 days of flooding respectively in 1973 and 1974, Tables 1 and 5.

Carya illinoinensis was tolerant of flooding if the plants were established at the time flooding began. All of the 1972 planted trees that were alive in the spring of 1973 withstood flooding of 100 days at Davis in 1973 and 1974. The same was true at Folsom. However, survival the first year was extremely low whether the trees were flooded or not. The tap-rooted planting stock was excessively large (1" caliper) and the planting date fairly late in 1973.

Species - Tolerant

Five species were classified as being tolerant to flooding, Table 1. At least 70% of the trees of each species survived 100 days of flooding in 1973 and 1974 at Davis. For each of the three years at Folsom the trees withstood 34 to 125 days of flooding. Each of the species at Folsom withstood flooding for at least 69 days one of the three years.

Shrub Selections

Four shrub (possibly small tree) selections were moderately tolerant to flooding, Table 1. All of the eight Cephalanthus occidentalis plants subjected to 100 days of flooding survived in 1973 and all but one did in 1974.

The three willow selections exhibited considerable tolerance at Folsom, surviving flooding of 134 to 190 days in 1974; they were completely submerged for 114 to 155 of these days. At Davis, only a little over half of the plants of each species survived 100 days of flooding.

Grass Species

'Tiff Green' bermudagrass was the only grass species that survived flooding, Table 6. It withstood 103 days of inundation and began growth within a week after the water receded. None of the other species survived either 61 or 103 days of flooding. The 'Tiff Green' variety appears less vigorous than common bermuda and formed many wiry stolons. The hybrid bermudas have the advantage of setting no viable seed so unwanted spread is minimized.

Andrus-Brannan Islands

The tree survey of these islands flooded in 1972 substantiated the tolerance of Eucalyptus camaldulensis and Taxodium distichum, Table 2. At least 85% of the more than 50 trees of each species survived flooding of 66 to 85 days. None of the trees were flooded more than 85 days.

Four other tree species exhibited tolerance to flooding, Table 2. All of the trees of 15 additional species survived 60 or more days of flooding, Table 7. However, there were only one to four plants of each species so more information must be obtained before a recommendation can be made as to their tolerance to flooding. Although it should be noted that all of the four *Carya illinoinensis* survived 73 to 92 days of flooding.

Other plants observed in the survey are listed in Table 8. Plants that were susceptible to flooding are listed in Table 9.

Influence of Establishment Period on Tolerance to Flooding

Trees of 16 species were planted at Davis in each of two succeeding years before being flooded to determine if trees established one year were more tolerant to flooding than those planted shortly before flooding.

Whether the trees had been planted only two months or for more than a year before being flooded had little influence on their tolerance to flooding (see 1974 Report for details). However, at Davis in 1973 the *Taxodium distichum* was planted later in the winter than the other species. This species had low survival whether flooded or not.

Side Effects of Flooding

Trunk Bending

Eight species tolerant to flooding at Davis exhibited weakened trunks due to submergence, particularly those which grew one season before flooding, Figure 5. Of these eight species planted in 1972, the trunks of 18-60% of the surviving trees bent almost horizontal near the high water line. The trees most affected were at the 2 to 4 foot depths. Of the eight species planted in 1972 that had weakened trunks due to flooding, seven of them also were planted in 1973. Four of these seven species exhibited the same trunk weakness as in 1972, though to a lesser extent.

On certain species, portions of the trunks which were submerged grew less in caliper than those portions above the water. This, coupled with the greater wind resistance of the taller trees of the 1972 plantings, could account for the higher percentage of trees with bent trunks in the 1972 than the 1973 plantings following the 1973 flooding at Davis.

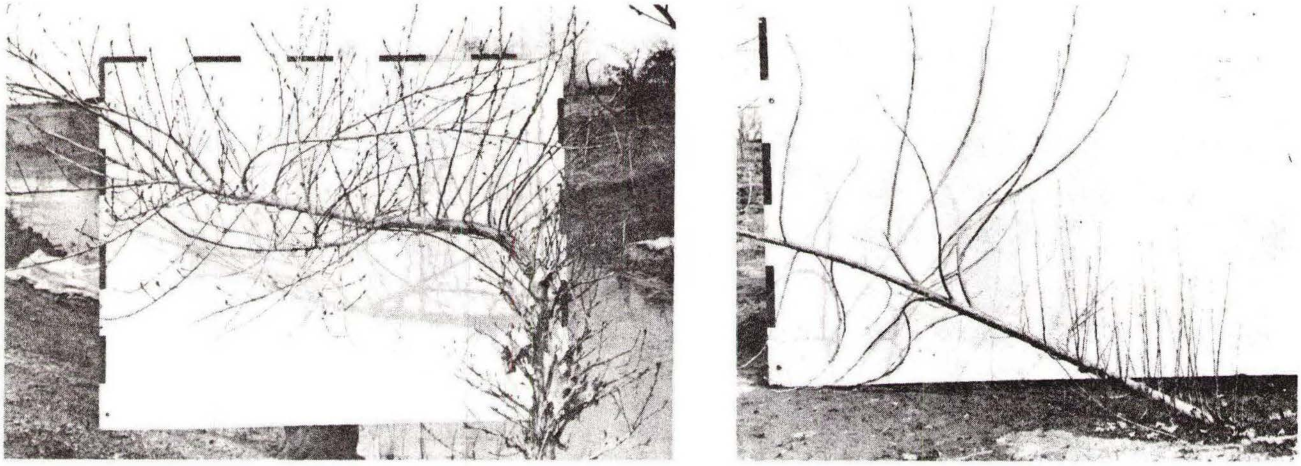


Figure 5. Flood Reservoir, Davis. Left. Bent trunk of Populus fremontii planted 6 feet below gross pool level following 1973 flooding. Note vertical shoots from horizontal portion of main trunk.

Right. Flooded root system of Populus candicans was unable to support the tree against prevailing winds. About one-third of the trees of this species were so affected. Photos taken March, 1974.

Again in 1974, trees of a number of species at Davis flooded for 100 days failed to develop sufficient trunk caliper and/or strength to hold their tops upright when the water level was lowered, Table 10. Of the seven species that had 18-60% of the trees bend in 1973, five species had 30-50% of the trees bend in 1974.

Trees were more subject to trunk bending due to flooding the second year after being planted than after the first year, Table 10. In 1973 for the 10 species where comparisons could be made, 30% of the trees planted in 1972 developed bent trunks compared to 10% of those planted in 1973. In 1974 the same species planted in 1973 had more bent trunks following flooding (35%). It appears tree height in relation to trunk development is the main problem.

The trees which had bent in 1973 were pruned back to an upright growing lateral just as they started growth in 1974. The severe pruning to an upright lateral did not predispose these trees to be more prone to bending in 1974. Of the trees that bent in 1974 an equal percentage of trees bent whether they had been severely pruned or not, Table 11.

The heavy growth of algae on the water surface added to the weight of the tree tops, particularly the smaller plants with multiple slender trunks.

Trunk bending was not a problem at Folsom; only one tree, Populus candicans, bent during 1974. This tree was 11 feet tall. The trunk bent at about two feet above the ground. The water had stood between this level and four feet on the trunk for about 70 days. The continuous high water level at Davis followed by the rapid drop at the end of the flooding period appears to have resulted in lack of trunk development in relation to the top that causes the tree trunks to bend. At Davis the algae and wind intensified the problem.

The tops of trees susceptible to bending should be thinned out as the water recedes to lighten the top and reduce wind resistance. This also should reduce transpiration and ease the transition from flooding to an arid situation.

About one-third of the flooded Populus candicans at Davis were not able to stand upright due to root systems inadequate to support the tops, Figure 5. The species was equally affected whether planted in 1972 or 1973. Trees flooded one to three feet deep were more affected than those deeper.

At Folsom, neither trunk bending nor weak root systems were problems. The trees at Folsom compared to those at Davis were not as tall, were not in the critical flooding depth (two to four feet) as long, nor subjected to as much wind during the growing season.

Trunk bending is not a serious problem since vigorous upright shoots occurred on the upper side of most bent trunks, Figure 5. The trunks were cut back to the best positioned upright shoot so it would continue as the main trunk. This will slow height increase but the lower trunk will become more sturdy to better support new top growth.

Weak root systems such as those of flooded Populus candicans are more difficult with which to contend and use of this species is seriously questioned for reservoir plantings, Figure 5.

Roots formed along the trunks of Salix alba 'Tristis' when submerged. When the water recedes these roots are unattractive.

Influence of Severe Pruning

Trees which bent during and following the flooding in 1973 were pruned severely to an upright-growing lateral just as growth began in 1974. About 75% of the tops of these trees were removed.

A higher percentage (40%) of the severely pruned trees succumbed to flooding in 1974 compared to trees of the same species not pruned or pruned lightly (12%), Table 10.

The severe pruning preceded the beginning of flooding by only two weeks and may have weakened the trees. If severe pruning were necessary it would seem best to do it as the water recedes.

Table 1. Species exhibiting tolerance to flooding at the Flood Reservoir, Davis, and at Folsom Lake, 1972, 1973, 1974.

	Davis			Folsom Lake			
Species	Survival			Maximum Days Survived			
	To 100-103 Days			Flooding			Complete
Considerable Tolerance	1973, %	1974, %	Both, %	1972	1973	1974	Inundation
Cynodon dactylon 'Tiff Green'	--	100	--	--	--	--	--
Eucalyptus camaldulensis	100	82	82	--	166	83	121
Salix alba 'Tristis'	71	100	71	147	144	171	125
Taxodium distichum	38	67	25	--	166	190	171
Moderate Tolerance							
Carya illinoinensis	100	100	100	124	103	143	125
Fraxinus pennsylvanica var. lanceolata	89	100	89	82	86	102	83
Gleditsia triacanthos var. inermis	89	100	89	34	60	83	53
Salix sp.-Terminus South	--	57	--	--	--	190	155
Salix sp.-Terminus North	--	60	--	--	--	155	134
Salix sp.-Folsom	--	57	--	--	--	134	114
Tolerant							
Acer saccharinum	95	82	70	82	34	53	9
Cephalanthus occidentalis	100	88	88	--	--	--	--
Platanus occidentalis	80	92	73	56	44	53	0
Populus x canadensis	88	86	75	82	55	102	0
P. fremontii	100	75	75	82	55	102	0
Salix matsudana	71	100	71	--	86	114	69

Table 2. Woody species exhibiting tolerance to flooding in the Sacramento-San Joaquin delta in 1969 and/or 1972.

	Sherman Island, 1969[1]		Andrus, Brannan Islands, 1972[2]	
Species	# of Plants	Survival, %	# of Plants	Survival, %
Acacia decurrens	5	100	1	100
Eucalyptus camaldulensis	25	96	100	90
Platanus acerfolia	8	50	25	92
Populus candicans	--	--	13	100
Quercus lobata	--	--	9	100
Salix piperi	8	100	--	--
Taxodium distichum	--	--	50	80
Washingtonia robusta	--	--	51	75

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[1] Plants subjected to 50 to 150 days of flooding with a maximum depth of 12 feet for 38 days. For more information see "Vegetation Management on Reservoir Recreation Sites", Summary Report, 1966-1971. July, 1971. Dept. of Environmental Horticulture, Univ. of Calif., Davis.

[2] Plants subjected to 60 to 112 days of flooding with a maximum depth of 13 feet for 33 days.

Table 3. Number and survival of plants subjected to two years flooding.

DAVIS FLOODING RESERVOIR
FALL, 1974

ELEVATIONS ——>			ABOVE HIGH WATER				-1 to -3				-4 to -6			
DAYS WATER OVER GROUND LEVEL ——>	73	74	0		0		69	61	81	84	100	101	103	103
SPECIES	PLANTED 72	73	N*	S*	H*	E*	N	S	H	E	N	S	H	E
1. Salix alba 'Tristis'	√		3	100	7	7	6	100	7	7	7	71	5	5
2. Gleditsia triacanthos var. inermis	√	√	7	100	8	8	14	100	5	5	16	100	4	4
3. Fraxinus pennsylvanica var. lanceolata	√	√	7	100	7	7	12	100	6	6	19	89	5	4
4. Cephalanthus occidentalis		√	3	66	2	2	6	100	2	2	8	88	1	1
5. Acer saccharinum	√	√	7	100	9	9	14	93	6	5	17	82	5	4
6. Eucalyptus camaldulensis	√	√	6	100	12	12	12	92	7	6	17	82	5	3
7. Platanus occidentalis	√	√	9	100	8	8	15	87	5	4	12	80	5	2
8. Populus fremontii	√		3	100	20	20	6	100	10	8	8	75	9	6
9. P. canadensis	√		3	100	19	19	6	100	9	9	8	75	9	4
10. Salix matsudana		√	3	100	5	5	6	83	6	6	7	71	5	4
11. Salix sp. - Terminus North		√	–	–	–	–	5	100	5	4	5	60	3	1
12. Salix sp. - Terminus South		√	2	50	3	3	5	100	5	3	7	57	4	3
13. Salix sp. - Folsom		√	2	50	3	3	6	83	5	5	7	57	4	1
14. Populus candicans	√	√	6	100	16	16	12	75	5	5	14	57	6	4
15. Platanus racemosa	√	√	6	66	6	6	11	100	4	3	14	32	5	2
16. Acer negundo		√	4	100	9	9	6	100	7	7	7	28	6	4
17. Carya illinoinensis	√	√	5	40	2	2	12	58	5	5	12	25	6	6
18. Taxodium distichum		√	2	50	3	3	6	33	1	1	8	25	2	1
19. Salix discolor	√	√	6	100	6	6	12	58	4	4	14	21	4	3
20. Populus alba	√	√	6	100	15	15	13	77	5	3	15	20	2	2
21. Eucalyptus bicolor	√	√	5	80	5	5	10	50	1	1	12	17	<1	<1
22. Betula verrucosa	√	√	7	100	7	6	12	58	7	6	13	15	5	3
23. Salix blanda		√	3	0	–	–	7	100	5	4	8	12	5	2
24. Diospyros virginiana		√	3	33	2	2	6	66	<1	<1	8	12	1	<1
25. Salix caprea	√		3	100	5	5	6	50	6	6	8	0	–	–
26. Eucalyptus cosmophylla		√	1	100	6	6	2	50	3	3	3	0	–	–
27. E. aggregata	√	√	2	100	8	2	4	25	4	4	4	0	–	–
28. E. camphora	√	√	7	100	10	10	11	18	8	8	13	0	–	–

*N - Number of plants assumed alive prior to flooding.
S - % survival after 2 years flooding.
H - Height or vertical growth potential. } Average of living trees (feet)
E - Effective height after corrective pruning.

Table 4. Water level and period of flooding, 1972, 1973, and 1974. Folsom Lake.

Elevation	Level From Gross Pool[1]	Water at or Above Level Beginning Date			Number of Days		
		1972	1973	1974	1972	1973	1974
466	+2	--	--	--	0	0	0
464	0	6/14	5/31	--	8	9	0
462	-2	5/24	5/25	6/7	34	24	17
460	-4	5/17	5/21	6/3	51	34	53
458	-6	5/12	5/18	5/30	56	44	69
456	-8	5/7	5/16	5/27	68	49	83
454	-10	5/2	5/14	5/16	82	55	102
452	-12	4/28	5/12	5/14	91	60	114
450	-14	4/24	5/9	5/10	102	68	125
448	-16	4/18	5/4	5/8	113	86	134
446	-18	4/15	4/30	5/5	124	103	143
444	-20	4/12	4/28	4/29	132	121	155
442	-22	4/7	4/25	4/23	147	140	171
440	-24	4/2	4/20	4/17	156	166	190
438	-26	3/28	4/16	4/10	168	179	207

[1] Gross pool is at elevation 464 feet.

Table 5. Survival and height of species subjected to flooding in 1972, 1973 and/or 1974.

PLOT SUMMARY
FOLSOM LAKE
SPRING, 1975

◢ N Alive
╫ Alive '73, Dead '74
╱ Dead '72, '73

N-Ht. (feet)

DAYS WATER AT OR ABOVE ELEVATIONS YEAR	ELEVATIONS +2	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	-22	-24
72	0		34		56		82		102		124		147	
73	0	9	24	34	44	49	55	60	68	86	103	121	144	162
74	0	0	17	53	69	83	102	114	125	134	143	155	171	190

	SPECIES	YEAR PLANTED ↓	+2	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	-22	-24
1.	Taxodium distichum	73		◢ 1'		╱		◢ 2'		◢ 1'		◢ 1'		◢ <1'		◢ <1'
2.	Salix sp. - Terminus South	74		╫		◢ 3'		◢ 5'		╫		╫		◢ 6'		◢ 4'
3.	Salix alba 'Tristis'	72	◢ 7'		╱		◢ 7'		◢ 7'		◢ 7'		╱		◢ 7'	
4.	Salix sp. - Terminus North	74		╱		◢ 4'		◢ 5'		◢ 5'		◢ 4'		◢ 3'		╱
5.	Carya illinoinensis	72	╱		╱		╱		◢ 5'		╱		◢ 4'		╱	
	Carya illinoinensis	73		╫		╱		╱		╱		╱		╱		╱
6.	Salix sp. - Folsom	74		╱		◢ 4'		◢ 3'		╱		◢ 3'		╱		╱
7.	Fraxinus pennsylvanica var. lanceolata	72	◢ 7'		◢ 7'		◢ 7'		◢ 5'		╱		╱		╱	
	Fraxinus pennsylvanica var. lanceolata	73		◢ 4'		╱		◢ 5'		◢ 3'		╫		╱		╱
8.	Salix blanda	73		╱		╱		◢ 3'		◢ 3'		╫		╱		╱
9.	Salix matsudana	73		╫		◢ 6'		◢ 4'		◢ 3'		╫		╱		╱
10.	Populus x canadensis	72	╱		◢ 11'		◢ 9'		◢ 10'		╱		╱		╱	
11.	Populus candicans	72	╱		◢ 9'		◢ 11'		◢ 10'		╱		╱		╱	
	Populus candicans	73		◢ 7'		◢ 6'		╫		╱		╱		╱		╱
12.	Populus fremontii	72	╱		◢ 4'		◢ 11'		◢ 10'		╱		╱		╱	
13.	Eucalyptus camaldulensis	73		◢ 8'		◢ 8'		◢ 6'		╫		╫		╱		╫
14.	Gleditsia triacanthos var. inermis	72	◢ 5'		◢ 7'		╱		╱		╱		╱		╱	
	Gleditsia triacanthos var. inermis	73		◢ 3'		◢ 3'		◢ 3'		╫		╱		╱		╱
15.	Acer saccharinum	72	◢ 7'		◢ 10'		╱		╱		╱		╱		╱	
	Acer saccharinum	73		◢ 3'		◢ 4'		╱		╱		╱		╱		╱
16.	Platanus occidentalis	72	◢ 9'		◢ 8'		╫		╱		╱		╱		╱	
	Platanus occidentalis	73		◢ 4'		◢ 3'		╱		╱		╱		╱		╱
17.	Platanus racemosa	72	◢ 7'		◢ 7'		╫		╱		╱		╱		╱	
	Platanus racemosa	73		◢ 4'		╱		╱		╱		╱		╱		╱
18.	Populus alba	72	╱		◢ 8'		╱		╫		╱		╱		╱	
	Populus alba	73		◢ 6'		╱		╱		╱		╱		╱		╱
19.	Eucalyptus aggregata	73		◢ 8'		╱		╱		╱		╱		╱		╱
20.	Eucalyptus cosmophylla	73		◢ 6'		╱		╱		╱		╱		╱		╱
21.	Salix discolor	72	╱		╱		╫		╱		╱		╱		╱	
	Salix discolor	73		◢ 3'		╱		╱		╱		╱		╱		╱
22.	Acer negundo	73		◢ 3'		╱		╱		╱		╱		╱		╱

18.

Table 6. Response of four grass species to flooding in 1974 at the Flood Reservoir, Davis.

			Survival % of Area Planted	
			Period Flooded	
Species	Date Planted	Planting Technique	61 Days	103 Days
Agropyron intermedium 'Oahe' (Intermediate wheatgrass)	12-14-73	Seed	0	0
Phalaris arundinaceae (Reed canary grass)	12-14-73	Seed	0	0
Festuca arundinacea (Alta fescue)	12-14-73	Seed	0	0
Cynodon dactylon 'Tiff Green' (Tiff Green bermuda)	3-20-74	Sod	100	100

Table 7. Woody species of which at least 50% survived 60 days or more of flooding, Andrus and Brannan Islands, June to December, 1972. Survey July, 1974.

Species and Common Name	Range of Flooding Depths		Water Overground		# of Plants	Survival
	High-ft.	Low-ft.	High-Days	Low-Days		%
Eucalyptus rudis (Desert gum)	13.0*	--	112	--	1	100
Populus candicans (Balm of Gilead)	10.5	4.0	97	61	13	100
Acer saccharinum (Silver maple)	10.0	5.8	94	72	4	100
Liquidambar styracyflua (Sweetgum)	10.0	4.0	94	61	2	100
Acer negundo (Boxelder)	10.0	4.0	94	61	4	50
Washingtonia robusta (Mexican fan palm)	9.7	5.0	92	66	51	75
Quercus palustris (Pin oak)	9.7	--	92	--	2	100
Platanus acerfolia (London plane tree)	9.7	4.0	92	61	25	92
Carya illinoinensis (Pecan)	9.7	6.0	92	73	4	100
Eucalyptus camaldulensis (Red gum)	8.3	5.0	85	66	100	90

Table 7 (cont.)

Species and Common Name	Range of Flooding Depths		Water Overground		# of Plants	Survival
	High-ft.	Low-ft.	High-Days	Low-Days		%
Eucalyptus sideroxylon (Mulga ironbark)	8.3	--	85	--	2	100
Taxodium distichum (Bald cypress)	8.3	5.0	85	66	50	80
Morus alba (Mulberry)	8.3	5.0	85	66	26	50
Ulmus sp. (Elm)	6.7	4.0	76	61	4	75
Washingtonia filifera (California fan palm)	5.0	--	66	--	1	100
Quercus lobata (Valley oak)	4.5	4.0	64	61	9	100
Fraxinus velutina 'Modesto' (Modesto ash)	4.5	4.0	64	61	4	100
Lavatera assurgentiflora (Tree mallow)	4.5	--	64	--	1	100
Punica granatum (Pomegranate)	4.5	--	64	--	1	100
Gleditisia triacanthos (Honey locust)	4.5	--	64	--	1	100
Chaenomeles sp. (Quince)	4.0	--	61	--	1	100
Ziziphus jujuba (Jujube)	4.0	--	61	--	1	100

*Arranged in descending order of maximum number of days one or more plants survived.

Table 8. Woody species intermediate in tolerance, or with limited observations.

	Maximum Depth & Time Plants Survived				Minimum Depth & Time Plants Died		
Scientific and Common Names	Depth-ft.	# of Days	# Plants Flooded	Survival %	Depth-ft.	# of Days	# Dead Plants[2]
Abelia grandiflora[1] (Glossy abelia)	.5	37	1	100	--	--	--
Acacia baileyana (Silver wattle)	--	--	--	--	1.0	42	1
A. melanoxylon (Black acacia)	4.0	61	5	100	--	--	--
Bambusa sp. (Bamboo)	2.5	52	2	100	--	--	--
Betula alba (White birch)	1.5	45	1	100	--	--	--
Buxus microphylla var. japonica (Japanese boxwood)	.5	37	Hedge	100	--	--	--
Callistemon citrinus (Bottlebrush)	1.5	45	6	100	4.5	64	2
Camellia japonica (Camellia)	1.5	45	4	75	1.5	45	1 Declining
Campsis radicans (Trumpet vine)	1.5	45	1	100	--	--	--
Cedrus deodara (Deodar cedar)	1.5	45	2	50	.5	37	1
Citrus sinensis (Navel orange)	4.5	64	7	86	4.5	64	2 Declining
C. paradisi (Grapefruit)	2.5	52	1	100	--	--	--
Crataegus oxycantha (English hawthorne)	.5	37	2	100	--	--	--

Table 8 (cont.)

	Maximum Depth & Time Plants Survived				Minimum Depth & Time Plants Died		
Scientific and Common Names	Depth-ft.	# of Days	# Plants Flooded	Survival %	Depth-ft.	# of Days	# Dead Plants
Cupressocyparis leylandii (False cypress)	1.5	45	1	100	--	--	--
Erica sp. (Heather)	.5	37	1	100	--	--	--
Euonymus japonica (Bigleaf euonymus)	1.5	45	1	100	--	--	--
Ficus carica (Fig)	1.5	45	6	100	--	--	--
Fortunella margarita (Kumquat)	1.5	45	1	100	--	--	--
Faxinus velutina (Arizona ash)	2.0	49	3	100	5.5	70	5
Genista sp. (Broom)	.5	37	1	100	--	--	--
Hedera helix (Ivy)	.5	37	1	100	--	--	--
Hydrangea macrophylla (Hydrangea)	.5	37	1	100	--	--	--
Illex x altaclarensis 'Wilsonii' (Wilson's holly)	2.5	52	1	100	--	--	--
I. cornuta (Chinese holly)	.5	37	1	100	--	--	--
Juglans hindsii (No. California black walnut)	1.5	45	9	89	.5	37	1 Declining

Table 8 (cont.)

	Maximum Depth & Time Plants Survived				Minimum Depth & Time Plants Died		
Scientific and Common Names	Depth-ft.	# of Days	# Plants Flooded	Survival %	Depth-ft.	# of Days	# Dead Plants
Juniperus chinensis 'Pfitzriana' (Pfitzer juniper)	.5	37	1	100	--	--	--
Lagerstroemia indica (Crape myrtle)	1.5	45	1	100	--	--	--
Leptospermum laevigatum (Australian tea tree)	.5	37	1	100	--	--	--
Ligustrum lucidum (Glossy privet)	.5	37	1	100	--	--	--
Lonicera sp. (Honeysuckle)	1.5	45	1	100	--	--	--
Malus sylvestris (Apple)	2.5	52	4	75	2.5	52	1 Declining
Melia azedarach (China-berry)	1.5	45	6	66	.5	37	2 Declining
Myrtus communis (Myrtle)	1.5	45	Hedge	100	--	--	--
Nandina domestica (Heavenly bamboo)	.5	37	1	100	--	--	--
Nerium oleander (Oleander)	4.5	64	15	53	4.5	64	7
Parthenocissus quinquefolia (Virginia creeper)	.5	37	1	100	--	--	--
Phoenix canariensis (Date palm)	1.5	45	2	100	--	--	--
Picea pungens (Colorado spruce)	.5	37	1	100	--	--	--

Table 8 (cont.)

Scientific and Common Names	Maximum Depth & Time Plants Survived				Minimum Depth & Time Plants Died		
	Depth-ft.	# of Days	# Plants Flooded	Survival %	Depth-ft.	# of Days	# Dead Plants
Pinus thunbergiana (Japanese black pine)	1.5	45	1	100	--	--	--
Pittosporum tobira (Mock orange)	.5	37	2	100	--	--	--
Platanus orientalis (Oriental plane tree)	2.5	52	17	100	--	--	--
Prunus caroliniana (American cherry laurel)	.5	37	1	100	--	--	--
Pyracantha fortuneana (Pyracantha)	2.5	52	3	100	--	--	--
P. sp. (Pyracantha)	1.5	45	3	100	2.5	52	1
Raphiolepis indica (Indian hawthorne)	.5	37	1	100	--	--	--
Ricinus communis (Castor bean)	.5	37	1	100	--	--	--
Robinia pseudoacacia (Black locust)	1.5	45	2	100	10.0	94	5
Salix sp. (Weeping willow)	15.0	125	26	52	12.0	106	10
S. sp. (Willow)	8.3	85	7	57	3.5	58	1
Rosa sp. (Rose)	3.5	57	5	100	4.5	64	1
Sequoia sempervirens (Coast redwood)	4.5	64	1	100	5.8	72	1

Table 8 (cont.)

	Maximum Depth & Time Plants Survived				Minimum Depth & Time Plants Died		
Scientific and Common Names	Depth-ft.	# of Days	# Plants Flooded	Survival %	Depth-ft.	# of Days	# Dead Plants
Syringa vulgaris (Common lilac)	.5	37	1	100	--	--	--
Tamarix sp. (Tamarix)	2.5	52	1	100	--	--	--
Thuja orientalis (Oriental arborvitae)	1.5	45	6	100	--	--	--
Trachelospermum jasminoides (Star jasmine)	1.5	45	1	100	--	--	--
Ulmus pumila (Siberian elm)	4.5	64	1	100	--	--	--
Viburnum suspensum (Sandanqua viburnum)	.5	37	1	100	--	--	--

---

[1] Alphabetical order.

[2] Number of dead plants at minimum depth or deeper.

Table 9. Woody species susceptible to flooding. Andrus and Brannan Islands, June to December, 1972. Surucy, July, 1974.

Species and Common Name	Range of Flooding Depths		Water Overground		# of Plants	Survival
	Low-ft.	High-ft.	Low-Days	High-Days		%
Prunus domestica (Plum)	.5[1]	10.0	37	94	9	0
Calocedrus decurrens (Incense cedar)	.5	9.7	37	92	3	0
Cupressus sempervirens (Italian cypress)	.5	--	37	--	1	0
Prunus persica (Peach)	.5	5.8	37	71	10	30
P. amygdalus (Almond)	1.5	2.5	45	52	5	0
Cedrus atlantica (Mt. Atlas cedar)	1.5	--	45	--	1	0
Pterocarya stenoptera (Chinese wingnut)	1.5	--	45	--	1	0
Eucalyptus globulus (Blue gum)	2.5	13.0	52	112	212	0
Prunus armeniaca (Apricot)	2.5	10.0	52	94	4	0
Thuja plicata (Giant arborvitae)	2.5	--	52	--	1	0
Juglans regia (English walnut)	2.5	5.8	52	72	34	12

Table 9 (cont.)

Species and Common Name	Range of Flooding Depths		Water Overground		# of Plants	Survival
	Low-ft.	High-ft.	Low-Days	High-Days		%
Pyrus communis (Pear)	2.5	4.5	52	64	9	44
Magnolia grandiflora (Southern magnolia)	4.5	--	64	--	1	0
M. x soulangeana (Saucer magnolia)	4.5	--	64	--	1	0
Olea europaea (Olive)	4.5	--	64	--	1	0
Aesculus sp.	5.5	--	70	--	1	0
Ailanthus glandulosa (Tree of Heaven)	5.8	--	72	--	20	0
Prunus avium (Cherry)	5.8	--	72	--	1	0
Populus nigra 'Italica' (Lombardy poplar)	5.8	12.0	72	106	213	5
Pinus radiata (Monterey pine)	10.0	--	94	--	4	0
Eriobotrya japonica (Loquat)	10.0	--	94	--	1	0

[1] Arranged in order of minimum depths at which plants died.

Table 10. Flooded trees exhibiting weak trunks at 2-4 foot depths. Flood Reservoir, Davis, 1973 and 1974.

	1972 Planting				1973 Planting			
	After 1973 Flooding		After 1974 Flooding		After 1973 Flooding		After 1974 Flooding	
Species	# Alive	% Bent	# Alive	% Bent	# Alive	% Bent	# Alive	% Bent
Acer negundo	-	-	-	-	6	0	6	16
A. saccharinum*	8	38	6	50	11	0	11	36
Betula pendula (B. verrucosa)*	2	50	0	-	6	0	5	40
Cephalanthus occidentalis	-	-	-	-	8	0	8	25
Diospyros virginiana	-	-	-	-	5	0	5	40
Eucalyptus camaldulensis*	8	25	8	38	8	38	8	50
Fraxinus pennsylvanica var. lanceolata*	7	14	7	29	9	0	9	0
Gleditsia triacanthos var. inermis*	8	12	8	12	9	0	9	0
Platanus occidentalis*	8	62	6	50	9	0	9	44
P. racemosa*	8	50	5	20	6	50	6	66
Populus alba*	6	33	4	0	8	12	5	20
P. x canadensis	8	0	8	25	-	-	-	-
P. candicans*	6	16	3	66	7	14	7	43
P. fremontii	8	12	7	28	-	-	-	-
Salix blanda	-	-	-	-	7	57	6	50
S. discolor*	6	16	4	0	4	0	1	100
S. matsudana	-	-	-	-	6	0	6	33
Salix sp. - Folsom	-	-	-	-	-	-	6	50
Salix sp. - Terminus South	-	-	-	-	-	-	6	50
Salix sp. - Terminus North	-	-	-	-	-	-	5	40
Taxodium distichum	-	-	-	-	5	20	4	50
*Summary of Species	69	30%	55	27%	77	10%	69	35%

Table 11. Influence of pruning severity two weeks before flooding on tolerance to 61-103 days of flooding. Davis, 1974.

	Lightly Pruned		Severely Pruned	
Species	# Pruned	% Dead	# Pruned	% Dead
Acer saccharinum	25	16	7	29
Betula pendula (B. verrucosa)	14	29	2	100
Carya illinoinensis	6	0	3	67
Eucalyptus camaldulensis	23	9	3	0
E. camphora	1	100	2	100
Gleditisia triacanthos var. inermis	22	0	5	0
Platanus occidentalis	16	6	7	14
P. racemosa	8	50	7	14
Populus alba	4	50	14	50
P. x canadensis	11	0	1	0
P. candicans	12	0	6	66
P. fremontii	8	0	5	40
Salix alba 'Tristis'	8	0	1	100
S. blanda	4	0	3	33
S. discolor	10	40	2	100
S. matsudana	7	0	2	50
Taxodium distichum	5	20	0	0
TOTAL	184	12.5%	70	40%

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